TLS BOOSTER MEASUREMENT AND OBSERVATION BY NEW BPM ELECTRONICS

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Abstract

Taiwan Light Source (TLS) is a 1.5 GeV synchrotron based light source and its booster synchrotron was delivered in 1992. Due to the new project Taiwan Photon Source proceeded at the same site, some up-to-date device are available now before TPS civil construction completed and temporarily adapted for TLS booster to improve its operations and measurements. The major parameters of the TLS booster synchrotron are measured. It also provides a chance to experience for the TPS project booster diagnostic.

INTRODUCTION

The TLS booster synchrotron was delivered in 1992 [1]. Some diagnostics devices of the TLS booster are obsolete and discarded after twenty years operation. Due to the limited budget and operation priority, the modification and upgrade has been postponed. Recently, there are the latest BPM electronics delivered for the new TPS project which is a 3-GeV synchrotron scheduled to commissioning in 2014. During the construction period of the TPS, the available BPM electronics is temporarily borrowed for the TLS booster measurement. The BPM cablings were also modified to acquire better signal quality during shutdown in August 2012 and Jan 2013. There are two advantages for these revised efforts: as test bed for the TPS project to practice hardware, software, and application development; to provide better understanding of characteristics of the TLS booster synchrotron. This report would focus on BPM electronics, tune monitor and perform some preliminary test to check functionality and performance.

BOOSTER BPM LAYOUT

Beam position monitor (BPM) in the TLS booster synchrotron was mounted 45 degrees on the chamber between the dipole and the quadrupoles. The lattice of the booster synchrotron is FODO type with periods of 12. There are 23 BPMs used around the synchrotron because one is used for a photon port. The past efforts to measure closed orbit and turn-by-turn position of in the TLS booster synchrotron during ramping from 50 MeV to 1.3 GeV are summarized in references [2]. Energy ramping of the TLS storage ring from 1.3 GeV to 1.5 GeV was done in 1995 to enhance x-ray emission. Later the booster synchrotron was raised from 1.3 GeV to 1.5 GeV in 1999 to provide full energy injection for the storage ring.

The BPM cabling and electronics were completely modified during shutdown in August 2012. BPM electronics has been borrowed from the TPS project. These BPM electronics will be available before TPS commissioning in 2014. The BPM electronics would provide various data flows for x, y, and sum signals including turn-by-turn, 10 kHz, 10 Hz data to allow various observations.

ORBIT OBSERVATIONS

With these available powerful diagnostics, parameters of the booster can be checked routinely. We performed several experiments including orbit, turn-by-turn data analysis, first turn constructing from ADC raw data. Results are summarized in this paragraph.

Phase Compensation from ADC data

As Figure 1 shown, cable length difference and flight time of electron bunch train will cause different arrival time which was observed on ADC data. Through ADC raw data, we could do phase compensation for each BPM such that the phase delay could be within one ADC sample (~ 8 ns). This ADC data could also be used to construct the first turn beam position data.

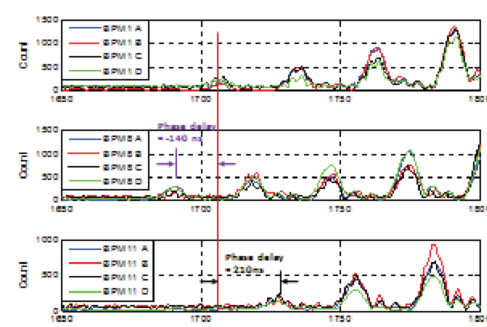


Figure 1: Arrival time variation due to different of cable length and BPM location. ADC counts increasing is due bunching process of the injected beam, strength of the 500 MHz signal components increasing which are detected by BPM.

Orbit Measurement

The extraction of the TLS booster is done by three bumpers excited by 2 msec half-sine current, a septum excited by 500 μsec half-sine and an extraction kicker by a PFN type pulser. The orbit excursion during the extraction process proceed is clear visible in Figure 2. The maximum beam excursion should appear at BPM within the three bumper magnet bump. However, the measurement shows that the extractions bump is not a closure bump. The BPM reading will help to adjust extraction condition setting of the booster synchrotron.

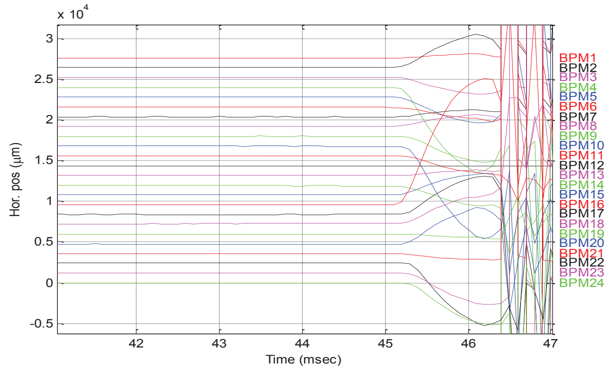


Figure 2: Horizontal beam position variation during beam extraction bumper magnets triggered.

Booster orbit stability is evaluated at top-up mode for 20 minutes as Figure 3. The average horizontal orbit stability is 10 um; vertical orbit is 5 um.

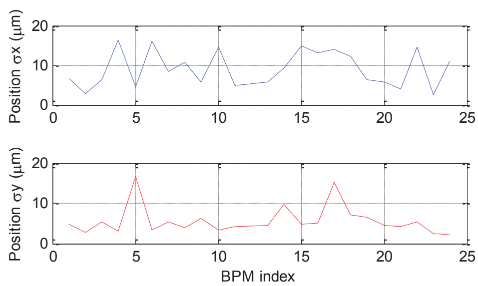
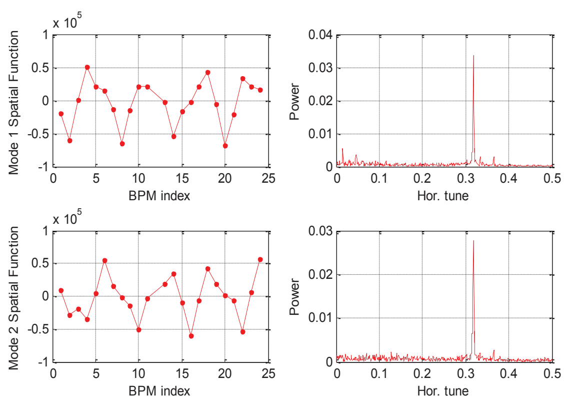
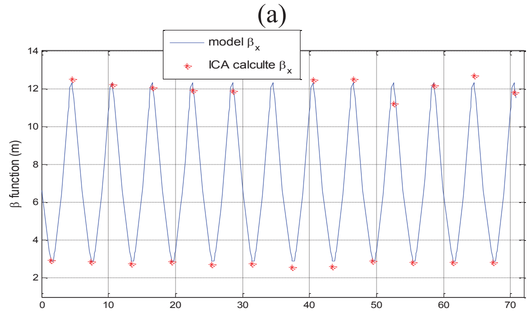


Figure 3: TLS booster orbit stability.



(a)



(b)

Figure 4: Preliminary results to apply ICA to calculate horizontal beta function using BPM turn-by-turn data. (a) Mode 1 and mode 2 spatial and temporal functions. (b) Beta Function.

Turn-by-turn Data Analysis

The BPM turn-by-turn data is used for independent component analysis (ICA) [3] to calculate horizontal beta function as Figure 4. The spatial and temporal function of ICA shows the integer part and the fractional part of horizontal tune are 4 and 0.31 respectively. The lattice is symmetric where odd BPMs location have low β_x value and even's BPMs are located at high β_x section. The ICA analysis result shows that they are consistence from model. Systematic study to improve reliability of BPM data by the usage of ICA is a short-term effort.

TUNE MONITOR SETUP AND MEASUREMENT

Initial tune measurement adopt extraction kicker as beam excitation and strength adjusted according to different energy and use digital oscillator to capture demodulated signal to extract tune [1, 4, 5]. It can provide horizontal and vertical kick simultaneously while it still takes many booster cycles for measurement to construct full cycle tune variation.

There are two stripline electrodes used on the TLS booster to measure tune. However, small shut impedance cause ineffective excitation in higher energy. Therefor the diagnostic X-Y kickers are modified as magnetic shaker. Multi-turn coils are mounted on the existed ceramic chamber of the diagnostic kicker. There are two coils in each plane enclosed surrounding ferrite box with ceramic chamber surrounding them. The kickers with 50Ω terminated load have calibration factor of 3 mG/A. The kickers are driven by a 50W amplifier in each plane. The turn-by-turn beam oscillation data is observed by the Libera Brilliance+ [6] BPM electronics. Agilent arbitrary signal generator would provide band-limited, strength-adjustable excite signal. The functional block diagram of this new tune monitor system is shown in Figure 5.

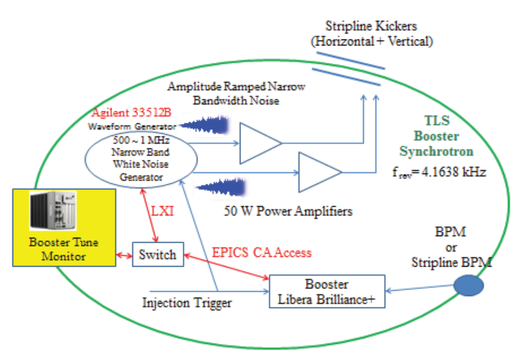


Figure 5: Functional block diagram of the new tune monitor for TLS booster.

Preliminary tests show that the beam can be excited effectively during the whole ramping cycle. The BPM can observed betatron sideband with acceptable signal to noise ratio as Fugure 6. The spectrogram of the horizontal and vertical of BPM turn-by-turn data could identify tune variation clearly.

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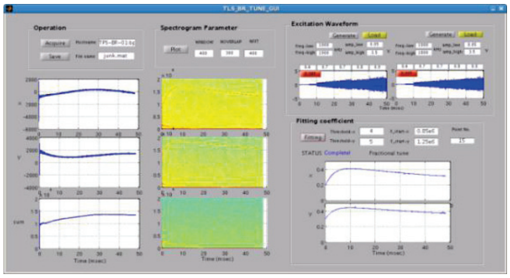

Figure 6: Tune monitor GUI.

Tune variation during ramping was observed in current routine operation. The fractional tune drift can be as large as 0.2. It is related to the tracking errors among focusing/defocusing quadrupoles and dipole as Figure 7. In cooperating with the monitoring system of FQ and DQ to dipole magnet strength, optimization of the booster working point can be efficiently achievable.

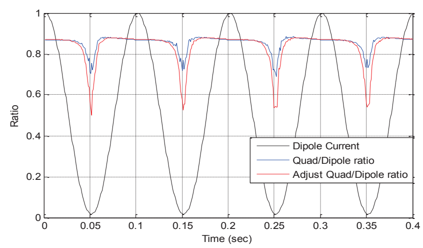

Figure 7: Tracking errors among quadrupole and dipole.

The beam loss is frequently observed due to the third resonance crossing when beam is excited while the small excitation will results in the measured tune blurred. There are two solutions: one is adjusting quadrupole to avoid the resonant. Fugure 8 shows the quadrupole is adjusted to avoid the vertical third order resonance and it does lower beam loss rate. The other solution is to put a notch filter with adequate bandwidth center at 1/3 resonance frequency to exclude beam excitation. This kind of excitation signal can be implemented by arbitrary generator easily.

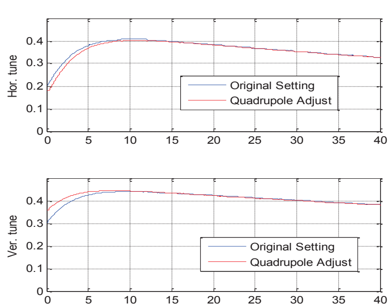

Figure 8: Quadrupole adjustment to avoid vertical 1/3 fractional tune resonant.

The chromaticity of booster was also calculated as RF frequency and measured tune change during the ramping. For a small variations, the chromaticity should be a linear function of the tune shift, $\xi_{x,y} = -\alpha_x f_{RF}\Delta\nu_{x,y}/\Delta f_{RF}$. The momentum compaction factor is normally a constant depending on the lattice. The measurement result is shown in Fugure 9.

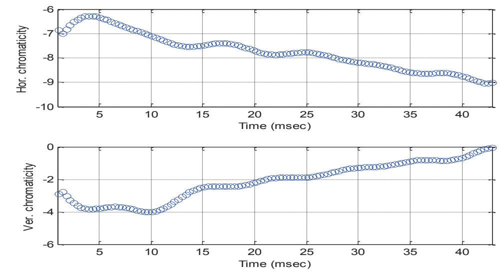

Figure 9: Measured uncompensated chromaticity.

SUMMARY

In this report, we performed some minor modification of the TLS booster synchrotron to modernize orbit, tune measurement. The system can be used as test bed for the similar system for the TPS booster synchrotron and software development. The schedule of TPS is still for one year, a plan to test hardware and software supporting are in proceeding. Plan to study the TLS booster synchrotron is also launched.

ACKNOWLEDGEMENT

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